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ROLE OF MICROFOSSILS IN INTERREGIONAL PENNSYLVANIAN CORRELATIONS

BY
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ROLE OF MICROFOSSILS IN INTERREGIONAL PENNSYLVANIAN CORRELATIONS[1]

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ABSTRACT

In the past the use of microfossils for long-distance correlations in the American Carboniferous has been somewhat restricted, largely because of the few workers interested in this class of fossils. Previous work has centered chiefly on the fusulines and ostracodes, and papers on these fossils have come mostly from the Mid-Continent region, as have also the relatively few papers on other Foraminifera and conodonts. More recent work on microfaunas from formations in the eastern Interior Basin and the West has shown that microfaunas, particularly some Foraminifera and the ostracodes, can be utilized as valuable tools in stratigraphic work.

INTRODUCTION

Three groups of microfossils, namely, the Foraminifera (particularly the fusulines), ostracodes, and conodonts have been employed in Pennsylvanian correlation studies. More than a quarter-century of work, however, has shown that the fusulines are much more useful than any of the others. In the chart and report of the National Research Council on the correlation of Pennsylvanian formations in North America[3] the fusulines are given first rank over other classes of fossils as zone markers in this system. Ostracodes have been little used in this system, largely because of the lack of sufficient work to determine diagnostic species in the several sedimentary basins. However, with the completion of three comprehensive reports—one on the Ardmore Basin, the second on the Kansas-Oklahoma area, and a third on the Illinois Basin—it is now possible to recognize a number of species that are good horizon markers. The work that has been done on Pennsylvanian conodonts has shown that, with few exceptions, the stratigraphic range of these fossils is too long for them to be useful as index fossils. This is also true of the Foraminifera other than fusulines.

Other types of microfossils, such as fragments of holothurians, echinoids, and other fossils, which include dissociated plates and other structural members, have received scant attention. Some work has been done on microcrinoids, but it is insufficient to be of stratigraphic value, except possibly at one or two horizons. Embryonic to youthful forms of the common larger fossils have been given little study or have been neglected entirely. Likewise, the Bryozoa represent, in general, a little-worked group, which probably would be of considerable stratigraphic value if more universally utilized. Some attention has also been given to sponge spicules. Finally, the diagnostic value of such things as scolecodonts, diatoms, radiolaria, molluscan radulae and opercula, and skeletal fragments of arthropods and fish is nil, largely either because of their sparse distribution or because of lack of sufficient data on which to make stratigraphic comparisons. The use of plant material, particularly microspores, will be discussed in another paper.

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[1] Published with permission of the chief, Illinois State Geological Survey.

[2] At the time this paper was prepared, Dr. Cooper was with the Illinois State Geological Survey.

[3] Raymond C. Moore *et al.*, "Correlation of the Pennsylvanian Formations of North America," *Bull. Geol. Soc. Amer.*, Vol. LV (1944), pp. 657–706 and chart.

FORAMINIFERA

The fusulines furnish many of the more useful fossils for the identification of Pennsylvanian formations, and the study of these forms in recent years has become a distinctly specialized branch of paleontology. Because of their structural complexity, relatively large size, and abundance in many marine zones, they make excellent guide fossils. As a result, they have been used extensively in zoning rocks of the Pennsylvanian and Permian systems, not only in North America but in many other parts of the world. A number of important papers have been published on the American Pennsylvanian forms, particularly in the Mid-Continent and contiguous areas. Many long-range correlations have been made with geologic sections outside North America, particularly those in Russia, China, and Japan—in fact, these fossils have been described from all continents.

The stratigraphic range of the Fusulinidae depends upon the classification favored. If those forms which are thought to be ancestral, such as *Endothyra*, etc., are considered true fusulines, the family extends into the Lower Mississippian or possibly even into the Upper Devonian. However, many have considered that the true fusulines are confined to the Pennsylvanian and Permian, and only recently have they been found in the Mississippian (*Millerella* of Illinois, Arkansas, and Wyoming).

The Pennsylvanian fusuline zones are based upon the predominant occurrence of the four genera, *Millerella*, *Fusulinella*, *Fusulina*, and *Triticites*. These zones overlap somewhat but correspond in the main to the groups and series of the system. Many have been further subdivided into subzones, based upon the occurrence of certain species or, in some cases, on certain genera. However, many species are geographically restricted to a single sedimentary province, having reacted to environmental conditions much as other animals do. An excellent discussion of Lower Pennsylvanian fusulines by R. C. Spivey and T. G. Roberts[4] appeared in a recent issue of the *Bulletin of the American Association of Petroleum Geologists*.

Millerella zone.—While this genus ranges from the lowest Pennsylvanian marine formations to as high as the Cisco of Texas, the *Millerella* zone has been designated by M. L. Thompson[5] as embracing those beds in which this genus occurs to the exclusion of other fusulines of the normal long-axis type. The zone is known to be well marked in Kansas, Arkansas, Oklahoma, Texas, New Mexico,[6] Utah, and Colorado;[7] and, no doubt, further work will show it to be present in other areas where marine rocks of Springer (Morrow) age are developed.

Fusulinella zone.—This genus characterizes the section above the Springer, containing beds of Atoka and lowest Des Moines age. It is present in the Pottsville (Mercer) limestones of Ohio, the Upper Marble Falls of Texas, the Tradewater

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[4] "Lower Pennsylvanian Terminology in Central Texas," *Bull. Amer. Assoc. Pet. Geol.*, Vol. XXX (1946), pp. 181–86.

[5] "Pennsylvanian Morrowan Rock and Fusulinids of Kansas," *Kan. Geol. Surv. Bull. 52*, Part VII (1944), pp. 409–31, Pls. 1, 2, Figs. 1, 2.

[6] M. L. Thompson, "Pennsylvanian System in New Mexico," *N.M. School of Mines Bull. 17* (1942).

[7] M. L. Thompson, "Pennsylvanian Rocks and Fusulinids of East Utah and Northwest Colorado Correlated with Kansas Section," *Kan. Geol. Surv. Bull. 60*, Part II (1945), pp. 17–84, Pls. 1–6, Figs. 1–11.

(Seville) of Illinois, and the lowermost Des Moines of Iowa. A lower subzone, characterized by *Profusulinella* (or *Fusiella* of Lee), and an upper zone, the *Fusulinella iowensis* subzone, are present. Only recently the suggestion has been made that a group of closely related species of *Fusulinella*,[8] which are characteristic of pre–Des Moines beds, be considered the "zone of *Fusulinella*," even though younger species are associated with *Wedekindellina* in higher zones.[9] Other genera commonly found associated with *Fusulinella* are *Millerella*, *Pseudostaffella*, and *Eoschubertella*.

Fusulina zone.—This zone, immediately above the *Fusulinella* zone, delineates all the Des Moines not included in the lower zone. Its upper boundary, the Des Moines–Missouri line, is the position of the most significant faunal break in the Pennsylvanian, not only for the fusulines but for many other classes of fossils as well. Although *Fusulina* is found with *Fusulinella* in the lowest Des Moines, it does not occur above the upper boundary of this series. Subzones are marked by *Wedekindellina* in the lower part and *Fusulina girtyi* and *F. exima* in the upper Des Moines. These zones are well marked in the Mid-Continent, Rocky Mountain, and central Interior basins. Only the upper subzone is known in Ohio, *Wedekindellina* apparently being absent there.[10]

Triticites zone.—Just as *Fusulina* is confined to beds below the Des Moines–Missouri boundary, *Triticites* is not found in the formations below the Missouri series of the Upper Pennsylvanian. However, it continues upward into the Lower Permian (Wolfcamp series). The zone is widespread in North America, and three zones, characterized by *T. irregularis*, *T. cullomensis*, and *T. ventricosus*, are recognized. In the lower zone *T. irregularis* is similar to *T. ohioensis* and appears to occur at about the horizon of the Kansas City group. Other genera, such as *Millerella*, *Schubertella*, *Waeringella*, and *Dunbarinella* make up only minor parts of the fusuline faunas of the Upper Pennsylvanian.[11] An excellent bibliography and systematic review of genera was published by Dunbar and Henbest.[12]

The smaller Foraminifera have not furnished horizon markers in the same proportion as have the fusulines. This is partly due to the lack of extensive work on these forms, but it is, in the main, due to the long range of most of the known genera and species, again reflecting the reappearance of like forms with the repetition of similar environmental conditions. Mrs. Plummer[13] has found, after her extensive work on the Texas section, that "most of the species have such long vertical ranges that they are of little value in this depositional province. Faunal assemblages apparently follow facies, and, with no major breaks in the sequence, faunas in general are repeated with repetition of facies in the column." In writing about the Marble Falls Foraminifera, she says:

> In this thick and almost consistently calcareous Marble Falls formation, a thin incidental noncalcareous and sandy layer is characterized wholly by the same forms that are so highly characteristic of superjacent noncalcareous and silty to sandy formations, and it emphasizes forcibly the need to study faunal groups in close association with obvious field

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[8] Thompson, p. 29 of ftn. 6.

[9] Spivey and Roberts, pp. 182–85 of ftn. 4.

[10] Carl O. Dunbar and Lloyd G. Henbest, "Pennsylvanian Fusulinidae of Illinois," *Ill. Geol. Surv. Bull. 67* (1942), p. 30.

[11] Thompson, p. 42 of ftn. 7.

[12] Ftn. 10.

[13] Personal communication.

TABLE 1*

SUMMARY FAUNAL CHART SHOWING FORAMINIFERA FROM LOWER PENNSYLVANIAN OF TEXAS

SPECIES	Marble Falls	Smithwick	Strawn	Unrestricted
Proteonina cervicifera Cushman and Waters				x
Thurammina texana Cushman and Waters				x
Thuramminoides sphaeroidalis, n. sp.				x
Hyperammina bulbosa Cushman and Waters				x
Hyperammina clavacoidea, n. sp.				x
Hyperammina elegantissima, n. sp.				x
Hyperammina spinescens Cushman and Waters				x
Hyperamminoides expansus, n. sp.				x
Earlandia minuta (Cushman and Waters)				x
Reophax arenatus (Cushman and Waters)			x	
Reophax asper Cushman and Waters				x
Reophax bendensis, n. sp.	x			
Reophax emaciatus, n. sp.				x
Reophax expatiatus, n. sp.			x	
Reophax fittsi (Warthin)				x
Reophax glennensis (Harlton)				x
Reophax minutissimus, n. sp.				x
Reophax tumidulus, n. sp.			x	
Ammodiscus semiconstrictus Waters				x
Glomospira compressa Waters		x		
Glomospira articulosa, n. sp.				x
Glomospirella umbilicata (Cushman and Waters)				x
Haplophragmoides confragosus, n. sp.				x
Ammobaculites minutus Waters				x
Ammobaculites stenomecus Cushman and Waters				x
Endothyra distensa, n. sp.	x			
Endothyra rotaliformis Warthin	x			
Endothyra whitesidei Galloway and Ryniker				x
Endothyranella armstrongi sobrina, n. subsp.	x			
Bradyina holdenvillensis Harlton	x			
Bradyina sp.	x			
Bigenerina perexigua, n. sp	x			
Cribrostomum marblense, n. sp.	x			
Cornuspira sp.	x			
Calcitornella sp.	x			
Trepeilopsis sp.	x			
Globivalvulina sp.	x			
Mooreinella biserialis Cushman and Waters				x
Polytaxis scutella (Cushman and Waters)	x			

*After Helen J. Plummer (see fn. 14).

relationships and with lithology of the enclosing strata, in order not to be misled by species.[14]

The available literature is very limited in scope and is published for the most part under the names of a small number of workers—namely, J. A. Cushman and J. A. Waters,[15] J. J. Galloway and B. H. Harlton,[16] J. J. Galloway and Charles Rynicker,[17] B. H. Harlton,[18] Helen J. Plummer,[19] Robert Roth and John Skinner,[20] A. S. Warthin,[21] and J. A. Waters.[22] Therefore, it is not possible, at the present state of our knowledge, to make comparisons between the smaller foraminiferal faunas of the various sedimentary basins of North America. My own information on the Illinois Pennsylvanian does not permit conclusions that are in any way different from those reached by Mrs. Plummer from her study of the Texas section.

Of the previously described species shown in Table 1, five have been found restricted to a single formation, three to the Marble Falls, and one each to the Smithwick and Strawn. In her analysis of the Texas faunas, Mrs. Plummer reports the new species *Hyperammina elegantissima*, *Reophax emaciatus*, *R. expatiatus*, and *R. tumidulus* as good markers for the Strawn, and *R. bendensis* for the Marble Falls. No restricted species were listed from the Smithwick, all species ranging upward into the Strawn.

OSTRACODES

There is a considerable volume of literature on the Pennsylvanian ostracodes of North America, consisting mostly of short papers on faunas that are very limited stratigraphically. In order to obtain a comprehensive stratigraphic summary it is necessary to examine this extensive literature describing many hundreds of species from scores of localities and formations, principally from the Mid-Continent and adjacent areas. The most important papers are by H. H. Bradfield,[23]

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[14] Helen Jeanne Plummer, "Smaller Foraminifera in the Marble Falls, Smithwick, and Lower Strawn Strata around the Llano Uplift in Texas," *Tex. Univ. Pub. 4401* (1945), p. 215.

[15] "Pennsylvanian Foraminifera from Michigan," *Contr. Cushman Lab. Foram. Res.*, Vol. III (1927), pp. 107–10, Pl. 22; "Arenaceous Paleozoic Foraminifera from Texas," *ibid.*, pp. 146–53, Pls. 26, 27; "The Development of *Climacammina* and Its Allies in the Pennsylvanian of Texas," *Jour. Paleon.*, Vol. II (1928), pp. 119–30, Pls. 17–20; "Some Foraminifera from the Pennsylvanian and Permian of Texas," *Contr. Cushman Lab. Foram. Res.*, Vol. IV (1928), pp. 31–35, Pls. 4–7; "Additional Cisco Foraminifera from Texas," *ibid.*, pp. 62–67, Pl. 8; "Upper Paleozoic Foraminifera from Texas," *Jour. Paleon.*, Vol. II (1928), pp. 358–71, Pls. 47–49; "Foraminifera from the Cisco Group of Texas," *Tex. Univ. Pub. 3019* (1930), pp. 22–81, Pls. 2–12.

[16] "Some Pennsylvanian Foraminifera of Oklahoma, with Special Reference to the Genus *Orobias*," *Jour. Paleon.*, Vol. II (1928), pp. 338–57, Pls. 45, 46; "*Endothyranella*, a Genus of Carboniferous Foraminifera," *ibid.*, Vol. IV (1930), pp. 24–28.

[17] "Foraminifera from the Atoka Formation of Oklahoma," *Okla. Geol. Surv. Circ. 21* (1930).

[18] "Some Pennsylvanian Foraminifera of the Glenn Formation of Southern Oklahoma," *Jour. Paleon.*, Vol. I (1927), pp. 15–27, Pls. 1–5; "Pennsylvanian Foraminifera of Oklahoma and Texas," *ibid.*, pp. 305–10, Pls. 52, 53; "Micropaleontology of the Pennsylvanian Johns Valley Shale of the Ouachita Mountains, Oklahoma, and Its Relationship to the Mississippian Caney Shale," *ibid.*, Vol. VII (1933), pp. 3–29, Pls. 1–7.

[19] "Calcareous Foraminifera in the Brownwood Shale near Bridgeport, Texas," *Tex. Univ. Pub. 3019* (1930), pp. 1–21, Pl. 1.

[20] "The Fauna of the McCoy Formation, Pennsylvanian, of Colorado," *Jour. Paleon.*, Vol. IV (1930), pp. 332–52, Pls. 28–31.

[21] "Micropaleontology of the Wetumka, Wewoka, and Holdenville Formations," *Okla. Geol. Surv. Bull. 53* (1930).

[22] "A Group of Foraminifera from the Dornick Hills Formation of the Ardmore Basin (Oklahoma)," *Jour. Paleon.*, Vol. I (1927), pp. 129–33, Pl. 22; "A Group of Foraminifera from the Canyon Division of the Pennsylvanian Formations in Texas," *ibid.*, Vol. I (1928), pp. 271–75, Pl. 42.

[23] "Pennsylvanian Ostracoda of the Ardmore Basin, Oklahoma," *Bull. Amer. Paleon.*, Vol. XXII, No. 73 (1935).

Coryell *et al.*,[24] B. H. Harlton,[25] W. R. Johnson,[26] and Betty Kellett.[27] Of these, two stand out because of their comprehensive study of ostracodes from a large stratigraphic section. Bradfield's report on the ostracodes of the Ardmore Basin, Oklahoma, describes the fauna from all the Pennsylvanian overlying the Springer formation. This section embraces some 3,000 feet or more of beds in the Dornick Hills, Deese, and Hoxbar groups, which range in age from Morrow to the top of the Missouri series. Kellett's reports involve the Pennsylvanian and Permian section of Oklahoma and Kansas and give the stratigraphic distribution of species in formations ranging from the base of the Missouri to the top of the Big Blue (Permian) series. The two reports overlap, in that each describes ostracodes from the Missouri series.

An analysis of the range of Paleozoic ostracode genera made a few years ago[28] showed that over half the Mississippian genera did not continue into the Pennsylvanian. In this category might be mentioned a few characteristic genera which are present in the Chester, such as *Bairdiolites*, *Carboprimitia*, *Chesterella*, *Denisonella*, *Graphiodactylis*, and *Perprimitia*. A like portion of the Pennsylvanian genera originate in the Mississippian or earlier, and, of these, about two-thirds continue into the Permian.

The results of my own studies on the Pennsylvanian of Illinois[29] give the ostracode faunas from zones ranging in age from Morrow to the top of the Virgil, representing the entire Mid-Continent section, except for some horizons present west of the Mississippi that are missing or unfossiliferous in Illinois. An analysis of all the available data shows that, when the total number of species is considered, comparatively few species are good horizon markers.

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[24] H. N. Coryell, "Some New Pennsylvanian Ostracoda," *Jour. Paleon.*, Vol. II (1928), pp. 87–94, Pl. 11, pp. 377–79, Pl. 51; H. N. Coryell and G. A. Osorio, "Pennsylvanian Ostracoda, and Ostracode Fauna from the Nowata Shale," *Amer. Mid. Nat.*, Vol. XIII (1932), pp. 25–40, Pl. 5; H. N. Coryell and Gladys D. Billings, "Pennsylvanian Ostracoda of the Wayland Shale of Texas," *Amer. Mid. Nat.*, Vol. XIII (1932), pp. 170–89; H. N. Coryell and C. H. Sample, "Pennsylvanian Ostracoda: A Study of the Ostracode Fauna of the East Mountain Shale, Mineral Wells Formation, Texas," *Amer. Mid. Nat.*, Vol. XIII (1932), pp. 245–81, Pls. 24–26; H. N. Coryell and R. T. Booth, "Pennsylvanian Ostracoda: A Continuation of the Ostracoda Fauna from the Wayland Shale, Graham, Texas," *Amer. Mid. Nat.*, Vol. XIV (1933), pp. 258–78, Pls. 3–5.

[25] "Some Pennsylvanian Ostracoda of the Glenn and Hoxbar Formations of Southern Oklahoma and the Upper Part of the Cisco Formation of Northern Texas," *Jour. Paleon.*, Vol. I (1927); pp. 203–12, Pls. 32, 33; "Pennsylvanian Ostracodes from Oklahoma and Texas," *ibid.*, Vol. II (1928), pp. 132–41, Pl. 21; "Pennsylvanian Ostracoda from Menard County, Texas," *Tex. Univ. Pub. 2901* (1929), pp. 139–61, Pls. 1–4; "Some Upper Mississippian (Fayetteville) and Lower Pennsylvanian (Wapanucka-Morrow) Ostracoda of Oklahoma and Arkansas," *Amer. Jour. Sci.*, Vol. XVIII, No. 105 (5th ser., 1929), pp. 254–70, Pls. 1, 2; see also ftn. 18 (1933).

[26] "The Ostracoda of the Missouri Series in Nebraska," *Neb. Geol. Surv. Paper 11* (1936), pp. 1–52, Pls. 1–5.

[27] "The Ostracode Genus *Hollinella:* Expansion of the Genus and Description of Some Carboniferous Species," *Jour. Paleon.*, Vol. III (1929), pp. 196–217, Pls. 25–26; "Ostracodes of the Upper Pennsylvanian and Lower Permian Strata of Kansas. I. The Aparchitidae, Beyrichiidae, Glyptopleuridae, Kloedenellidae, Kirkbyidae, and Youngiellidae," *ibid.*, Vol. VII (1933), pp. 59–108, Pls. 13–16; "Ostrocodes from the Upper Pennsylvanian and Lower Permian Strata of Kansas. II. The Genus *Bairdia*," *ibid.*, Vol. VIII (1934), pp. 108–38, Pls. 14–19; "Ostracodes of the Upper Pennsylvanian and Lower Permian Strata of Kansas. III. Bairdiidae (*concl.*), Cytherellidae, Cyprinidae, Entomochonchidae, Cytheridae, and Cypridae," *ibid.*, Vol. IX (1935), pp. 132–66, Pls. 16–18; "Carboniferous Ostracodes," *ibid.*, Vol. X (1936), pp. 769–84.

[28] Chalmer L. Cooper, "Occurrence and Stratigraphic Distribution of Paleozoic Ostracodes," *Jour. Paleon.*, Vol. XVI, No. 6 (1942), pp. 764–76.

[29] "Pennsylvanian Ostracodes of Illinois," *Ill. Geol. Surv. Bull. 70* (1946).

TABLE 2*

Chart Showing Pennsylvanian Faunal Zones

AGE	APPALACHIANS		MIDCONTINENT AND CENTRAL INTERIOR BASIN								
	SER.	FLORAL ZONES	SER.	GROUPS	BRACHIOPODS	AMMONITES	CRINOIDS	FUSULINES ZONE	FUSULINES SUBZONE	OSTRACODES	CONODONTS
PERMIAN	DUNKARD	Callipteris	WOLFCAMP	ADMIRE		Perrinites		Schwagerina	S. emaciata S. huecoensis	Kellettina robusta	
PENNSYLVANIAN	MONONGAHELA	Odontopteris	VIRGIL	WABAUNSEE	Lissochonetes,	Uddenites	Delocrinus vulgatus	Triticites	T. ventricosus	Bairdia concava	Streptognathodus elongatus
		Danaeites		SHAWNEE					T cullomensis	Hollinella moorei	Prioniodus? conflexus
		Lescuropteris		DOUGLAS	Chonetes transversalis						
	CONEMAUGH	Pecopteris	MISSOURI	PEDEE LANSING	Chonetina	Eothallaoceras	Apographiocrinus typicalis			Hollinella radlerae	Gondolella spp
				KANSAS CITY					T. irregularis	Bairdiacypris deloi	
				BRONSON		Prouddenites				Bairdia spinosa	
				BOURBON							
	ALLEGHENY	Neuropteris flexuosa	DES MOINES	MARMATON	Mesolobus mesolobus	Owenoceras	Delocrinus granulosus	Fusulina	F. exima F. girtyi	Silenites lenticularis	Gondolella magna G. cruvata
		Neuropteris rarinervis		CHEROKEE	Marginifera muricatina	Wellerites	Plaxocrinus mooresi		Wedekindellina	Cavellina equalis	Idiognathus acutus
	KANAWHA	Neuropteris tenuifolia	TI VALLEY	ATOKA	Marginifera nana M. haydenensis Mesolobus striatus	Paralegoceras		Fusulinella	F. iowensis	Bairdia ardmorensis	Streptognathodus n. sp.
		Cannophyllites							Profusulinella		
	LEE	Mariopteris pygmaea		MORROW (Springer)	Hustedia miseri	Gastrioceras	Stereobranchi-crinus	Millerella	M. marblensis	Polytylites wapanuckensis	Polygnathus wapanuckensis
		M. pottsvillea Aneimites									
		N. pocahontas M. eremopteroides				Branneroceras			M. inflecta		Streptognathodus ouachitensis
MISS.	MAUCH CHUNK	Rhodea goepperti	CHESTER		Composita subquadrata	Eumorphoceras	Proterocrinus	Millerella spp.		Bairdiolites Carboprimitia	Cavusgnathus cristata

* In part after Moore *et al.*, 1944.

Ti Valley series.—This name is suggested in the Illinois report as a solution for the Morrow-Atoka-Lampasas–Marble Falls nomenclatural problem and includes the Morrow and Atoka groups, the latter being used with the stratigraphic connotation of Spivey and Roberts.[30] The series is characterized by *Ectodemites harltoni*, from the Johns Valley shale and the Ferdinand of southern Indiana, and *Kirkbya bendensis*, from the same zones. The lower part of the series, the Morrow, contains the distinctive *Polytylites wapanuckensis* as well as *Monoceratina ardmorensis*. In the Atoka group the lower Ferdinand formation contains *Bairdia ardmorensis* and *Ectodemites plummeri* from the Dornick Hills and Marble Falls, respectively. The next higher formation, the Seville, does not have the restricted species common to zones in the Mid-Continent, but several new species appear to be restricted in the Illinois Basin.

Des Moines series.—In the Mid-Continent and Illinois Basin areas this series provides a number of species common to both groups and formations. *Cavellina equalis* is found in the lowest group, the Cherokee, and *Coryellites cooki* is characteristic of the Liverpool and upper Deese.

The Marmaton group contains *Geisina gregaria*, *Microparaparchites brazoensis*, and *Silenites lenticularis*. The Summum contains *Healdiacypris perplexa* from the upper Deese and the Brereton, while *Geisina gallowayi*, *Jonesina dubia*, and *Bairdia citriformis* are from comparable horizons in the west. The position of the Lonsdale near the top of the Des Moines is indicated by such species as *Cavellina cavellinoides*, *C. lintris*, *Hollinella nowataensis*, *Jonesina deesensis*, and *Microparaparchites cuneatus*. The next higher formation, the Exline, contains *Cavellina jejuna*, *Healdia formosa*, and *Jonesina trisulcata*.

Missouri series.—*Kirkbya arcuata* marks this series, but no species are known to be restricted to the oldest group, the Bronson. The Kansas City is indicated by *Bairdiacypris deloi* and *Jonesina infrequens*. In the Lansing group the La Salle–Livingston-Millersville zone is characterized by *Hollinella radlerae*, *Bairdia hooverae*, *B. lunata*, *Ectodemites sullivanensis*, and *Bairdiacypris haydenbranchensis*, the first three from the upper Missouri of the Mid-Continent and the other two from Indiana.

Virgil series.—The Virgil contains *Bairdia scholli* and *Cavellina laevis*, which also are found in the upper formations of the Illinois section. The Shawnee Little Vermilion formation contains *Healdia masoni* and *Knightina ampla*, while the Newton-Shumway zone has *Bairdia pinnula*, *Cavellina nebrascensis*, *Healdia coryelli*, *Hollinella moorei*, and *Silenites silenus*. The youngest Illinois formation, the Woodbury, is marked by *Ectodemites edsonae*, present in the Hoxbar of Oklahoma, somewhat lower in the section. Kellett's work has shown that "almost all of the Permian ostracode genera are found also in late Pennsylvanian strata, and with few exceptions, the same genera predominate. Many of the common species in earliest Permian faunas are Pennsylvanian survivals, but in addition a dozen new species occur. By mid-Permian (Leonard) time few Pennsylvanian species survived, although a number of close relatives may be recognized. In general mid-Permian ostracodes are more highly ornamented than Pennsylvanian species, especially in the families Kirkbyidae and Kloedenellidae."[31]

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[30] P. 185 of ftn. 4; see also Cooper, ftn. 30.

[31] Personal communication.

CONODONTS

Conodonts, so numerous and varied in the Upper Devonian and Lower Mississippian, while still rather plentiful in the Upper Mississippian and Pennsylvanian, are represented by few genera and species in the younger system. They are quite numerous in the black shales, which have furnished the many assemblages that have been described. The literature contains comparatively few papers on Pennsylvanian conodonts, the principal workers being Samuel Ellison,[32] F. H. Gunnell,[33] and C. R. Stauffer and Helen J. Plummer.[34] Like many other classes of fossils, conodonts are creatures of environment and so, like many other Pennsylvanian forms, are largely of long stratigraphic range. The most important stratigraphic and taxonomic study[35] shows that nearly all species lived throughout Pennsylvanian times. One species, *Cavusgnathus giganta*, apparently started in the Chester and lived on into the Permian. Very little is known about conodonts from the Upper Mississippian or from those formations classed as "Mississippian and/or Pennsylvanian." As in other transition zones, genera from both systems are found, such as *Cavusgnathus*, *Gnathodus*, and *Metalonchodina*. The following details of the fauna and the chart are summarized from Ellison's report:[36] Species of *Prioniodus*, *Ligonodina*, *Lonchodina*, *Hibbardella*, *Prioniodina*, *Synprioniodina*, *Ozarkodina*, *Spathodus*, and *Hindeodella* are present throughout the system, some being restricted, many extending into the Permian.

Ti Valley series.—The only described fauna from this series is that of Harlton,[37] and this contains only three species. Two features distinguish this series, namely, *Polygnathodella* is known only from the Morrow, and *Gondodella* is not known to range below the base of the Des Moines.

Des Moines series.—The most important feature of this series is the presence of large numbers of idiognathodids, but the only restricted species is *Idiognathodus acutus*. *Gnathodus* and *Metalonchodina* are also rather abundant and are not known in younger formations. While *Gondodella* is not common, *G. curvata* and *G. magna* are characteristic of several zones within the Marmaton.

Missouri series.—Most striking is the abundance of idiognathodids, streptognathodids, and gondodellids: *I. lobatus*, *Streptognathodus sulcatus*, *S. concentricus*, and *S. oppletus* are confined to the series. There is a noticeable disappearance of many idiognathodids near the top of the Missouri. *Gondodella dubia* is confined to the Hushpuckney member of the Swope formation, and *G. symmetrica* to the Stark shale member of the Dennis, both in the Bourbon group. Two species of *Cavusgnathus*—*C. lauta* and *C. flexa*—begin in the Missouri but carry on into the Permian.

Virgil series. — Streptognathodids, mostly *S. elegantulus*, make up over three-fourths of the Virgil fauna. Here *S. elegantulus* and *Prioniodus conflexus* appear for the first time and continue into the Big Blue series. All gondodellids except *Gondodella denuda* and *G. elegantula* disappear in zones above the lower Virgil Lecompton formation.

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[32] "Revision of Pennsylvanian Conodonts," *Jour. Paleon.*, Vol. XV (1941), pp. 107-43, Pls. 20-23; "Conodonts as Paleozoic Guide Fossils," *Bull. Amer. Assoc. Pet. Geol.*, Vol. XXX, No. 1 (1946), 93-110.

[33] "Conodonts from the Fort Scott Limestone of Missouri," *Jour. Paleon.*, Vol. V (1931), pp. 244-52, Pl. 29.

[34] "Texas Pennsylvanian Conodonts and Their Stratigraphic Relations," *Tex. Univ. Bull. 3201* (1932), pp. 13-50.

[35] Ellison, ftn. 33 (1941).

[36] *Ibid.*, pp. 108-11, Fig. 4.

[37] See ftn. 18 (1933).

This analysis of conodont faunas pertains to the Pennsylvanian of Missouri and Kansas. There are no comparable faunal data covering other sedimentary basins. Outside of a few papers on Oklahoma formations by Harlton[38] and by R. W. Harris and R. V. Hollingsworth,[39] the only other comprehensive Pennsylvanian conodont paper is by Stauffer and Plummer[40] on the Texas Pennsylvanian. My own observation is that there is little variation in conodont faunas throughout the whole system or from one sedimentary basin to another. They seem to follow ecological conditions closely, and faunas are found to be repeated numerous times under the multiple repetition of similar beds during this system. The few possibilities for guide fossils are the platform types, which have furnished the small number of restricted forms that are now known. Even these may possibly be shown to have considerable range by future work. More reports like that by Ellison are needed for other areas.

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[38] *Ibid.*

[39] "New Pennsylvanian Conodonts from Oklahoma," *Amer. Jour. Sci.*, Vol. XXV (5th ser., 1933), pp. 193–204, Pl. 1.

[40] See ftn. 34.